Integrating Usability Engineering in the Iterative Design Process of the Land Attack Combat System (LACS) Human Computer Interface (HCI)

Ana Theresa Borja
Space & Naval Warfare Systems Center
33560 Hull Street
San Diego, CA 92152-5001
619-553-3651
ana.borja@navy.mil

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Abstract

Usability engineering are the set of design and development practices the Space & Naval Warfare Systems Center (SSC San Diego) followed in order to ensure that the Tomahawk Operators can succeed in using the Land Attack Combat Systems (LACS) for its intended purposes. This paper presents our approach of the usability engineering activities and the results from a 1-year Fiscal Year 2003 effort for the development of the LACS Human Computer Interface (HCI). Iterative usability evaluations and design processes were conducted quarterly on the LACS HCI in order to develop the HCI that best supported the tasks of the Tomahawk Operators. Usability evaluations consisted both of Heuristic Reviews and Usability Testing. Results from these iterative evaluations were integrated into successive design builds for further evaluations.

Introduction on LACS

Increasingly new weapons and new controls capabilities and requirements will continue to increase the demands placed on Navy operators. The capability for small team of operators to plan for simultaneous control and launch of multiple weapons types is highly desirable. Designing an effective HCI that provides this capability, without increasing current manning requirements, workload or situational awareness levels is future challenges (Kellmeyer, Lulue, Osga, and Campbell, 2001). Funded by two Future Naval Capability's (FNC) of the Office of Naval Research (ONR), SSC San Diego is leading the work on the development of the LACS HCI. This effort is the ATTD Transition Candidate for TTWCS version 6 that will enhance the current Tactical Tomahawk Weapons Control Systems (TTWCS) version 5 HCI.

The LACS HCI consists of two displays: The Task Manager and TacSit. The Task Manager provides the TTWCS team an interface for supervisory control of all Tomahawk Land Attack Missile taskings. Supervisory control allows the team members to work in collaboration with automation as well as each other. The TacSit provides the situational awareness plot with enhanced capability to provide the TTWCS operators with increased situational awareness and understanding to quickly see the tactical situation.

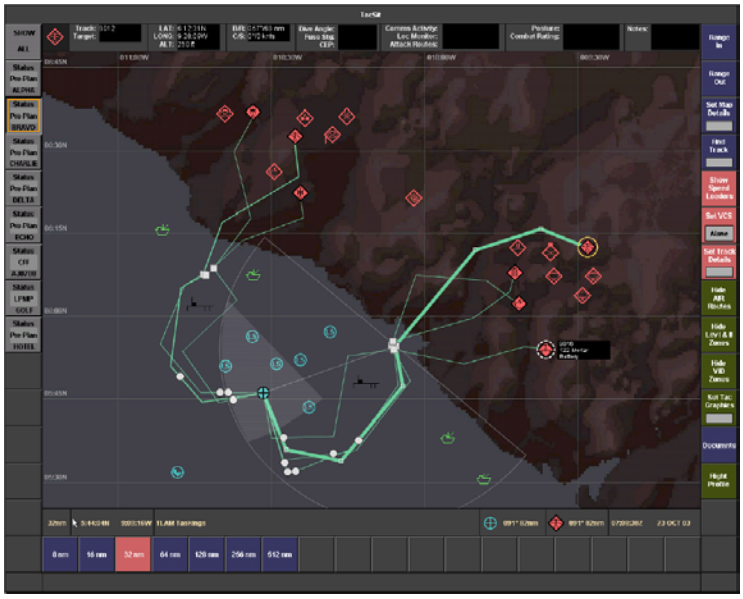

Figure 1.0 Task Manager (Situational Awareness)

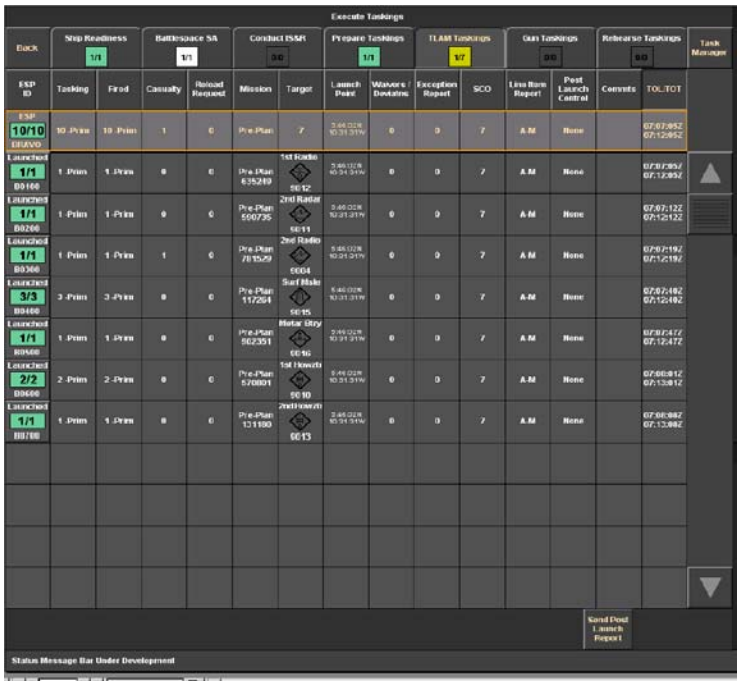

Figure 2.0 TacSit (Task Management)

Importance of Usability Engineering for the LACS HCI

Employment of the Usability engineering process produces highly usable LACS HCIs that are essential to increased productivity and timeliness, reduced manning, reduced mental workload, reduced training, reduced human error, and warfighter trust. It is the systematic application of established human factors engineering expertise and

practices. Usability development practices offer a means of quantifying, designing, and testing the system's "fit" to the warfighter and their tasks. Activities in this engineering process include, but not limited to, task analysis, user and environment profiles, rapid prototyping, heuristic reviews, and usability testing.

Too often, many program managers and developers misunderstand usability engineering add cost and development time to the product's development lifecycle. However, applying usability engineering in the product's lifecycle reduces cost over the life of the product's development, by reducing the need to add missed or fix unusable functionality later in the development cycle. As part of SSC San Diego's spiral development, Human Factors Engineers apply the usability engineering process and iteratively perform heuristic evaluations and usability testing in the design of the LACS HCI. These evaluations were conducted rather cost effectively, but we gained valuable insight on how the warfighters use and perceive the LACS HCI. This paper will focus on these usability evaluations and present the process and results that stemmed from these activities.

Heuristic Evaluations of the LACS HCI

Heuristic evaluation is the most cost-effective usability evaluation of the usability engineering process, intuitive to conduct, and extremely effective in the early phases of the development process. It is a technique in which one or more experts evaluate a design according to established usability principles (heuristics). Human Factors Engineers trained in cognition theory and human factors principles review the product and judge the usability of the product against these heuristics. Potential usability issues are identified and then used to derive recommendations for improving the HCI. To increase the effectiveness of the LACS HCI heuristic evaluation, multiple Human Factors Engineers from SSC San Diego, NAVAIR Orlando Training Systems Division, and NSWCDD independently performed heuristic evaluations on the prototype interface. Studies have shown that independent evaluations conducted by three to five Human Factors Engineers identify most of the potential usability issues (Nielsen, 1993). Each Human Factors Engineer evaluated the interface independently. The results are then combined to analyze common and conflicting results. The evaluations were conducted quarterly on various versions and different levels of fidelity of the HCI. Depending on the development cycle, the interface may have been a power point presentation or a high fidelity running prototype with automation and instantaneous feedback from the warfighters action. Over the course of the FY 2003 effort, a total of over 200 potential usability issues were found on various versions of the LACS HCI. The usability recommendations found from these heuristic evaluations were folded into subsequent version of the HCI for usability testing or documented for additional research.

Usability Testing

In a well-managed project, usability testing occurs at various times throughout the development lifecycle to ensure the usability of the product. Usability testing is a method in which real users of the intended product do real tasks. Trained Human Factors Engineers analyze the data, diagnose the real problems and recommend changes to fix the problems. Throughout FY 03, for the purpose of evaluating alternative design concepts, usability tests were conducted quarterly on initial LACS HCI designs. Usability tests were conducted quarterly at SSC San Diego and NSWCDD. A total of 34 fleet personnel from various facilities acted as participants. The participants include: FCTCPAC, FCTCLANT, USS Stethem DDG, USS Winston Churchill DDG-81, and COMSECFLT. Participants were recruited from various locations to provide a wider range of feedback. This was also to account for differing opinions and operating procedures from the various locations.

Figure 3.0 Participant in a usability study

Methodology

There are different types of usability tests conducted on the product at various stages of the development phase. During FY 03, the type of methodology conducted was an Exploratory Usability Test. An Exploratory usability test is a method best used to determine or explore the efficiency and effectiveness of the design concepts, also known as the user's conceptual or mental model. In this type of usability test, the participants are solicited for their ideas of the design concepts presented to them and how to improve any confusing areas. There is much discussion between the Test Administrator and the participants since the goal is to understand their thought processes and for the participants to answer questions posed to them by the Test Administrator. As the HCI matures and as the development phase moves from conceptual to design, the type of usability tests will move from qualitative feedback to quantitative performance metrics, also known as Validation testing.

Low fidelity testing with power point presentations was conducted early in the development cycle to explore the operator's mental model and design concepts. High fidelity usability testing was conducted with simulated prototypes to analyze how well the warfighters can perform full-blown tasks. A total of 6 usability tests were conducted in FY 03. Over 300 usability issues were found and recommendations provided to improve the LACS HCI. As with the heuristic evaluations, recommendations were folded into the subsequent versions of the HCI for further testing.

For each usability test, 5 – 7 participants participated in the usability test at SSC SD and NSWCDD. Participants were only required to have familiarity with the subject matter. The evaluations used a scenario that required the warfighters to complete a TTWCS taskings. The warfighters were allowed to freely navigate the HCI. This allowed the opportunity to observe the intuitiveness of the interface by using a discovery type method, as well as the subsequent learnability of the interface. As the participants moved through the various displays, the Test Administrator asked various questions regarding the usability of the displays. These questions were designed to elicit information on the intuitiveness, effectiveness and efficiency of the HCI and whether the information presented supports their taskings. The administrator recorded if the operator took the expected actions or gave the expected answer. The administrator and data logger also recorded any observations or operator comments.

Results

Results from FY 03's usability study indicated the LACS HCI effectively supports the warfighter's tasking. Effectiveness was measured as whether the information provided the needed information to complete their taskings, whether the warfighters launched the missiles on time, and anecdotal feedback that one warfighter can accomplish the taskings of a team of Tomahawk operators. Other anecdotal feedback states the warfighter's approval of the LACS HCI over the current HCI. Lastly, additional research questions were raised and are the focus of FY 04 activities.

References

Kellmeyer, D., Lulue, D., Osga, G., and Campbell, N. (2001). *User-Centered Design for Land Attack Warfare: Advanced Tactical Technology Demonstration (ATTD) (Tech. Rep. No. 1880).* San Diego, CA: SPAWAR Systems Center (SSC).

Nielsen, J., *Usability Engineering*, Academic Press. 1993.

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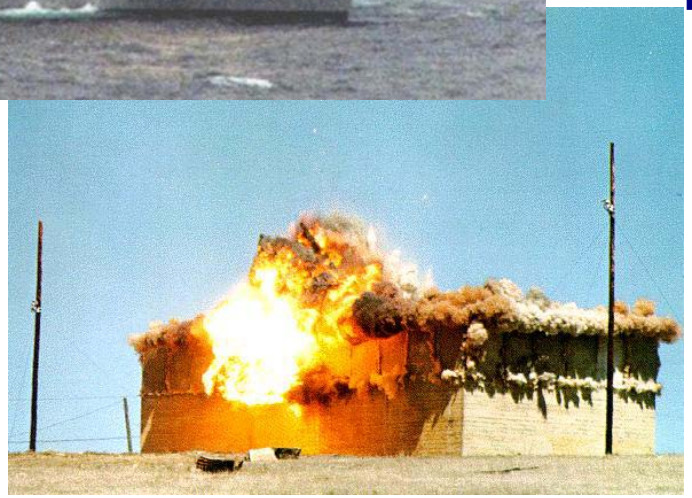
Systems Center
San Diego

Integrating Usability Engineering in the Iterative Design Process of the Land Attack Combat System (LACS) Human Computer Interface (HCI)

Presented by:

Ana Theresa Borja
Human Factors Engineer
Space & Naval Warfare Systems Center

Overview of LACS



- Study funded by two Future Naval Capability of the Office of Naval Research
- ATTD Transition Candidate for Tactical Tomahawk Weapon Control System (TTWCS) version 6 & 7
- SSC-SD leading work of the HCI development

LACS FNCs Team

- Government Labs
  - SPAWAR Systems Center - San Diego, CA
  - NAVSEA - Dahlgren, VA
  - NAVAIR - Orlando, FL
  - Naval Submarine & Medical Research Lab, Groton, CT
- Industry & Federally Funded Labs
  - Johns Hopkins Applied Physics Laboratory, MD
  - Pacific Science & Engineering Group Inc., CA
  - Southeastern Computing Consultants Inc., VA
  - Lockheed Martin Advanced Technology Labs, NJ
  - Lockheed Martin Mission Data Systems, PA
- Universities
  - University of Virginia
  - University of Michigan

UCD Team

SPAWAR Systems Center San Diego

NAVSEA DAHLGREN

NAVAIR ORLANDO TRAINING SYSTEMS DIVISION

NSMRL NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY

THE JOHNS HOPKINS UNIVERSITY APL

PSE Pacific Science & Engineering

SCCI SOUTHEASTERN COMPUTER CONSULTANTS INC

LOCKHEED MARTIN ATL

Advanced Technology Laboratories

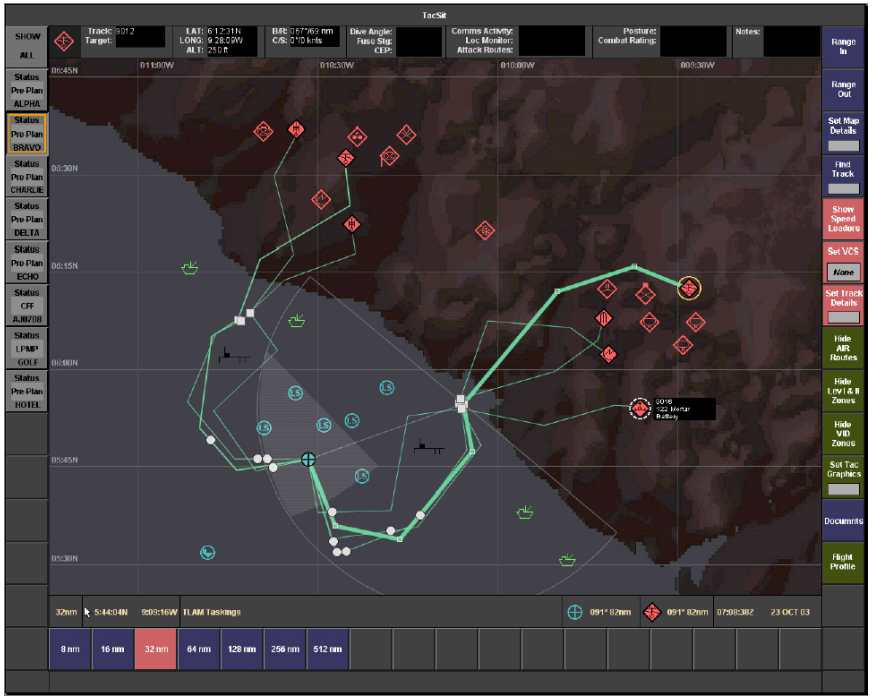
UVa

THE UNIVERSITY OF MICHIGAN 1817

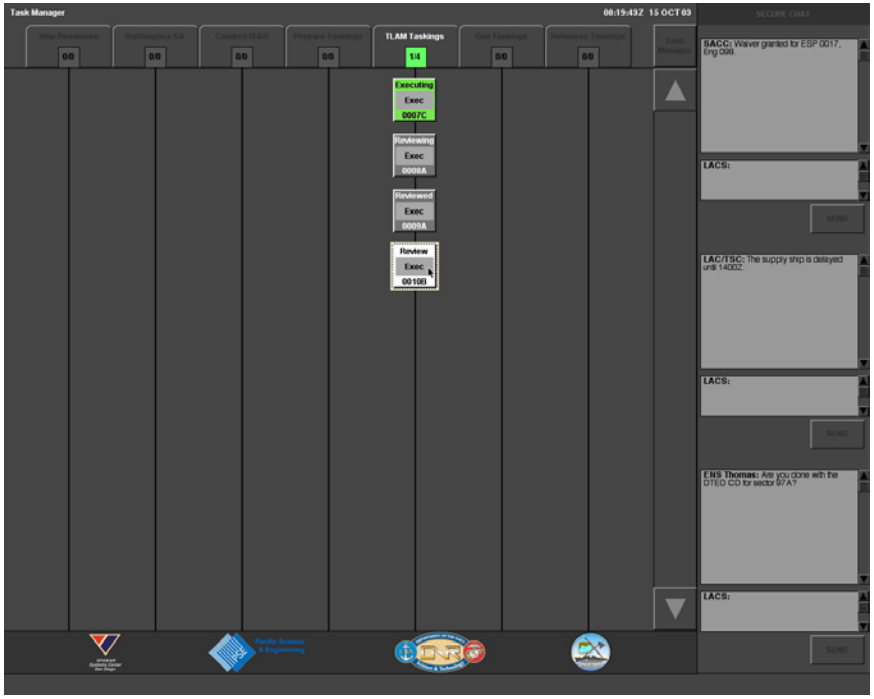
TTWCS TACTICAL TOMAHAWK WEAPONS CONTROL SYSTEM

Usability Engineering for the LACS HCI

LACS HCI



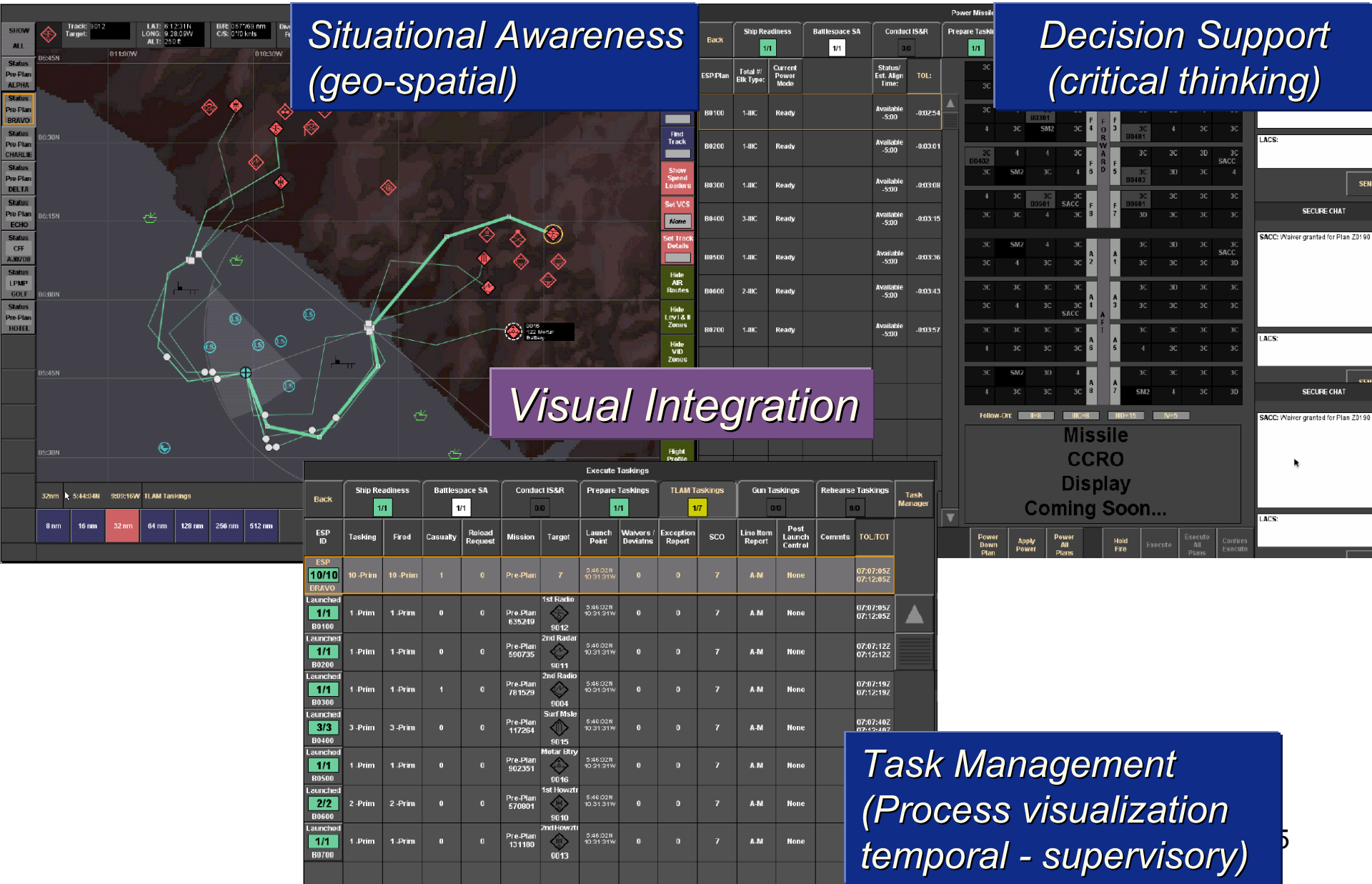
TacSit

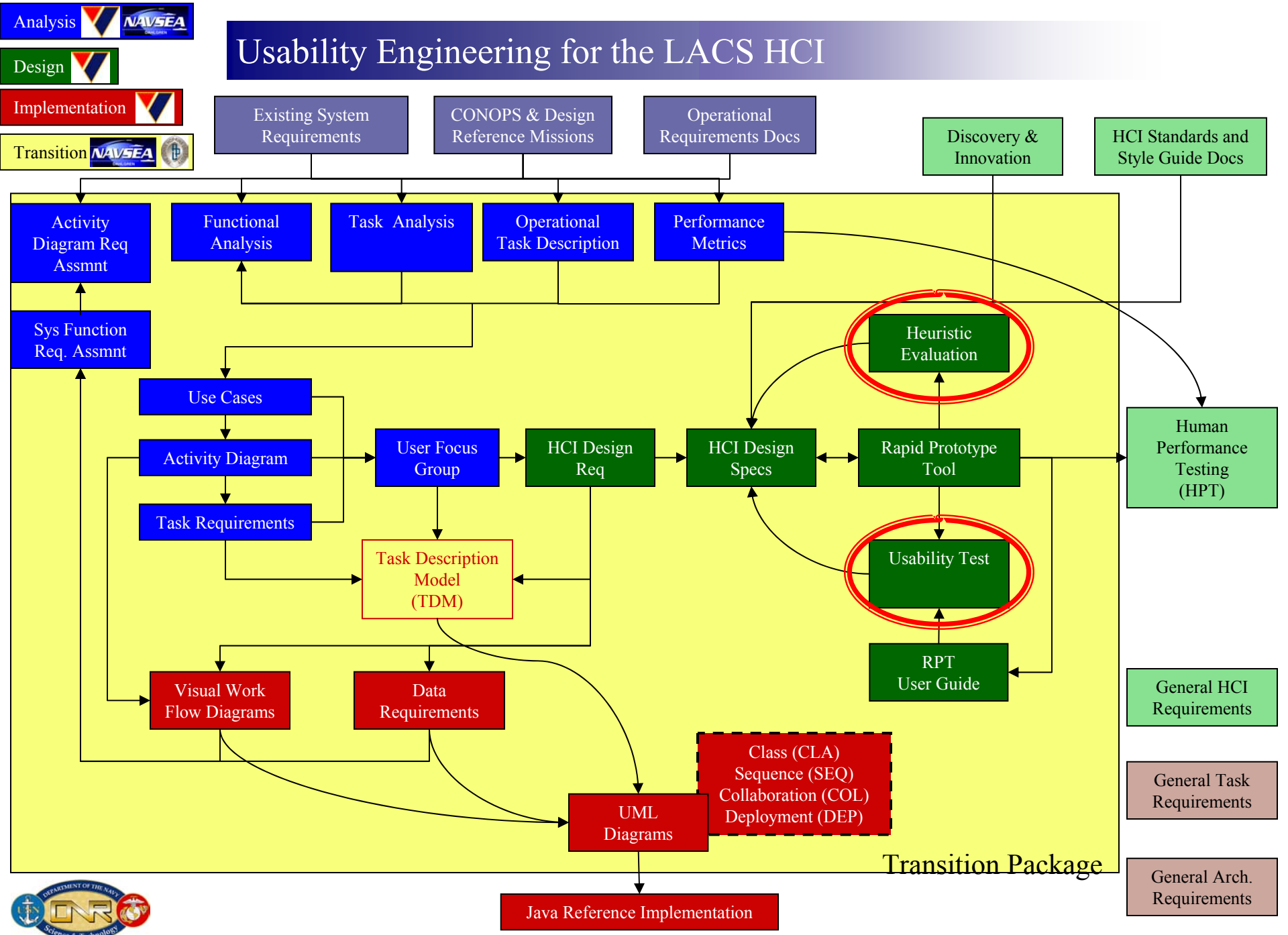


Task Manager

SPAWAR Systems Center San Diego

Usability Engineering for the LACS HCI

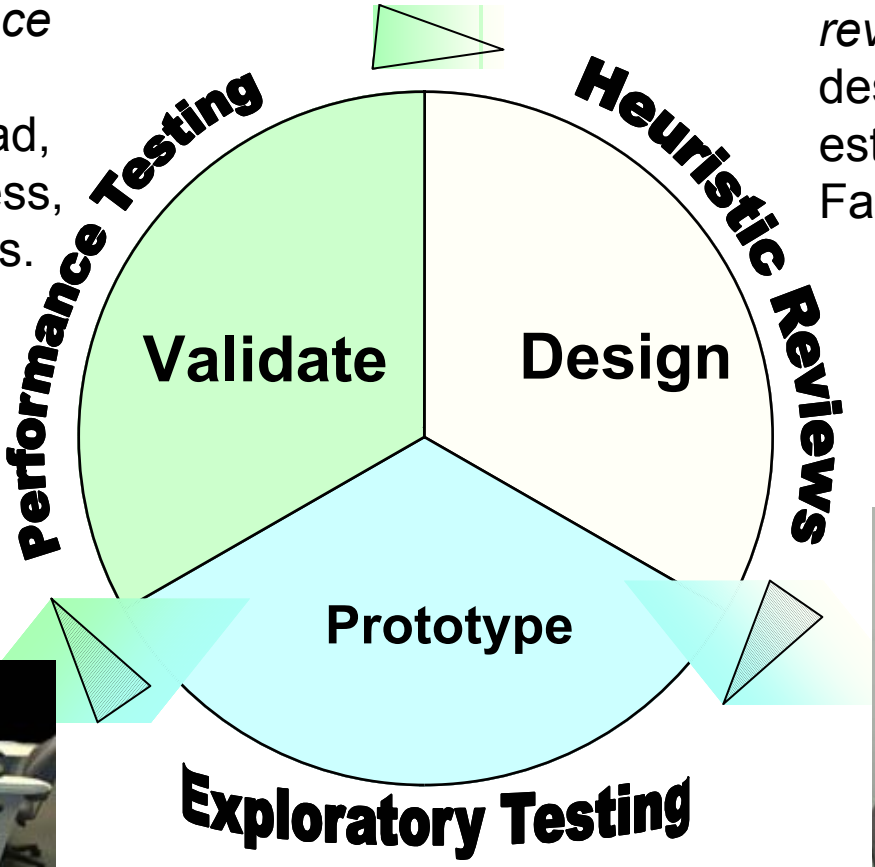



Analysis
Design
Implementation
Transition
Usability Engineering for the LACS HCI
Existing System Requirements
CONOPS & Design Reference Missions
Operational Requirements Docs
Discovery & Innovation
HCI Standards and Style Guide Docs
Activity Diagram Req Assmnt
Functional Analysis
Task Analysis
Operational Task Description
Performance Metrics
Sys Function Req. Assmnt
Heuristic Evaluation
Use Cases
Activity Diagram
Task Requirements
User Focus Group
HCI Design Req
HCI Design Specs
Rapid Prototype Tool
Human Performance Testing (HPT)
Task Description Model (TDM)
Usability Test
RPT User Guide
Visual Work Flow Diagrams
Data Requirements
General HCI Requirements
Class (CLA)
Sequence (SEQ)
Collaboration (COL)
Deployment (DEP)
UML Diagrams
General Task Requirements
Transition Package
General Arch. Requirements
Java Reference Implementation

Usability Evaluation Within Spiral Development

Conduct *performance testing* to measure throughput, workload, situational awareness, and team processes.

Conduct *heuristic reviews* to ensure designs follow established Human Factors principles.

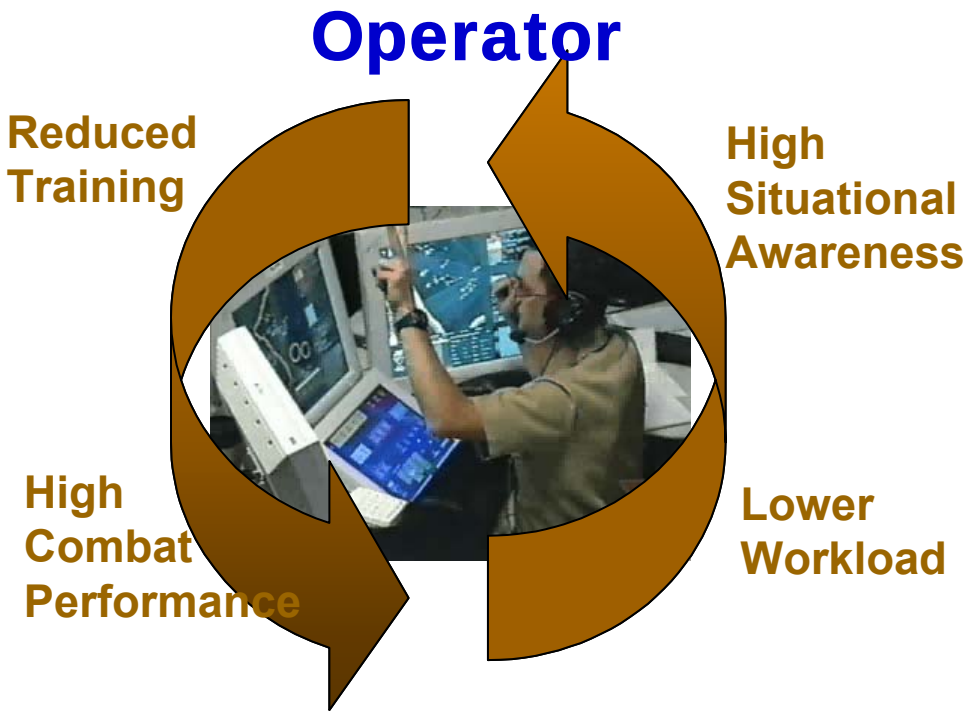


Conduct *exploratory testing* to iterate on initial designs and evaluate alternative design concepts.

Usability Evaluation Objectives

OPNAV Guidance

". . . our ability to effectively and successfully employ Land Attack Warfare systems will directly reflect our commitment to Human Centered Design, Human Systems Integration and Optimal Manning . . ."



➔ Increase the combat effectiveness of Fleet Land Attack operators without increasing their workload, providing high situational awareness while reducing training time.

Why is Usability Important?

- Systems need to be "user-friendly" to increase:
  - User efficiency
  - Productivity and Timeliness
  - Situational Awareness
  - User trust
- Workload reduction
- Training reduction
- Can determine success or failure of a system

Fleet Buy-in!

Quarterly Usability Evaluations

- Focus of User Taskings Per Quarter
  - Q1 – Call For Fire (CFF), Mission Data Update (MDU), and a prepare pooled missiles task
  - Q2 – In-Flight Missile Health and Status monitoring screen
  - Q3 – Post Launch Monitor Phase
  - Q4 – Year-end Operability Test
- HCI constantly evaluated every quarter
- Improvements are made and re-tested the following quarter
- Validate design changes

Usability Evaluation Methodology

- Heuristic Evaluation (HE)
  - HSI engineers individually evaluate the RPT against a set of usability criteria (called heuristics).
- Usability Testing (UT)
  - An inspection method of usability evaluations. Includes formal testing with fleet participants.

Types of Usability Studies

1.Exploratory
Explore concept of design & "user's mental model"

Paper prototype, Power Point, or Simulated system

2.Assessment
How well can user perform full-blown realistic task

Simulated system

3.Validation
Verification of product's usability, compares to established benchmark

Simulated or Real system

4. Comparison
Compare to alternative design

Paper, Power Point, Simulated or Real System

Rubin, 1994, Handbook of Usability Testing

Heuristic Evaluation Process

- Compare the LACS interface to established usability criteria ("heuristics")
- Conducted by HSI Engineers from SSC-SD, NSWCDD, and NAVAIR Orlando independent evaluated the LACS interface
- Report with prioritized usability issues
- Over 200 improvement recommendations
  - Many implemented and others require additional research

Heuristics

1. **Visibility of system status**
2. **Match between system and the real world**
3. **User control and freedom**
4. **Consistency and standards**
5. **Error prevention**
6. **Recognition rather than recall**
7. **Flexibility and efficiency of use**
8. **Aesthetic and minimalist design**
9. **Help users recognize, diagnose, and recover from errors**
10. **Help and documentation**

Nielsen, J. (1994). Heuristic evaluation. In Nielsen, J., and Mack, R.L. (Eds.), Usability Inspection Methods. John Wiley & Sons, New York, NY.

Usability Testing Process

- Participants are real users
  - Total of 46 fleet participants individually tested. Include participants from FCTCPAC, FCTCLANT, USS Stethem DDG-63, USS Winston Churchill DDG-81, COMSECFLT
- Used real operational scenarios
  - Only 15 minutes spent explaining the scenario and minimum training on layout, symbology and color-coding
- Observed and recorded participants actions and comments
- Conducted low-fidelity usability tests using paper prototypes to explore design concepts and understand user needs
- Conducted high-fidelity usability tests using working prototypes to assess how well the sailors performed realistic tasks and to verify interface usability

Video of Usability Tests

Usability Evaluation Findings

- 9 heuristic evaluation reports
  - Tables summarized issue, location, heuristic violated, recommendation, and priority
- 6 usability testing reports
  - Tables included summary of design recommendations, and relevant operator comments

Table 1. Post Launch Monitor Interface Design Recommendations

Rec #	Design Recommendation	Comment # Referenced
Missile Timelines		
1	Recommend implementing a click and drag capability on the timebars (like the hand in Acrobat with pdf files).	A1:9
2	Recommend duplicating the minute header at the bottom of the screen. It is tough to lineup timelines that are farther down on the page with the timescale at the top.	A1:9
3	Recommend that the missile timeline still show flex options even though they have been passed and were not selected. Maybe gray it out and put a black "X" through it to denote that this flex was missed or not selected.	A1:10
4	Recommend that the new timeline/aimpoint not appear on the timeline until the transmission has finished processing or . . . **Alternate Recommendation:** For any option of redirecting an in-flight missile, instead of updating the original timeline after processing a request, have a new branch split off below the original timeline. This will help show the exact point in which the missile redirects and, most importantly, it will allow for quick and easy comparison of the new branch and the original branch.	A1:10
5	Make the symbology clearer so the operator can more easily determine when the last possible second is to make a retargeting or flex decision. Is it the beginning of the tangent line?	A1:10

Usability Testing Results

- Over 300 recommendations for new design ideas and improvements
- Implemented design changes were rolled into future builds for validation testing

Usability Testing Results

1. Indicated interface effectively supports user taskings
   - Provided needed information to complete their taskings
   - Many operators launched missiles on time
   - One operator can accomplish same taskings than that of a team of Tomahawk operators
2. Met operators' approval

"I like this, this is sweet."

"Still impressed. Impressed every time we come out here."

"Like the displays, the layouts, the colors."

"A lot of data, but it's not too much, especially if there's only 1 operator. Everything is covered. Looks good to me."

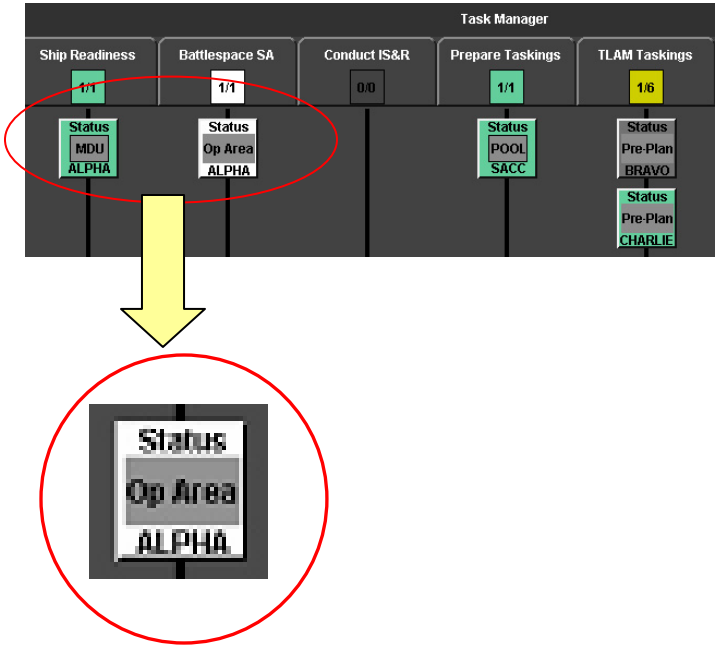
3. Raised additional research questions

HCI Improvements

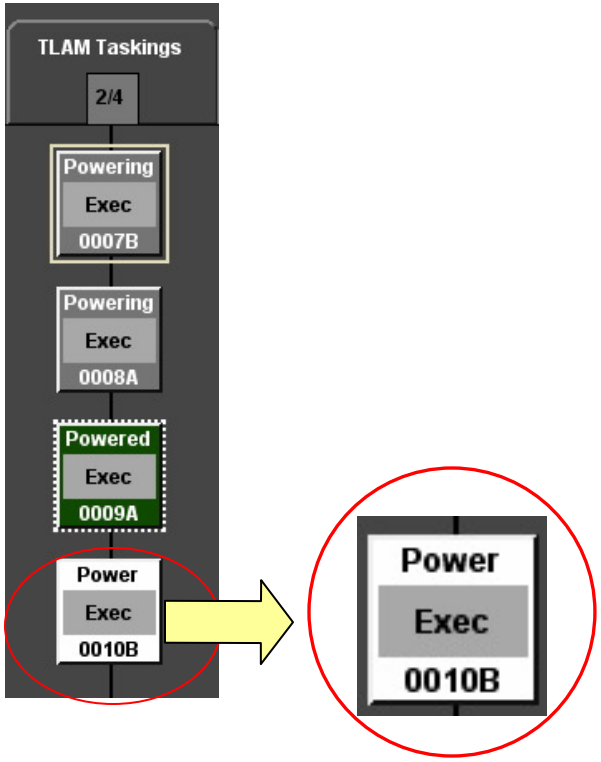
- Better understanding of operator's mental model, fleet CONOPS, and tasks
- Improved color coding scheme
- Provided better feedback as to what LACS is completing and what taskings operator needs to accomplish
- Provided needed information and better organization of information to support operator tasking
- Improved phraseology
- Improved navigation and less searching
  - Provided needed information at a higher level and detailed information in a lower level
  - Decreased number of drill down interfaces
- Provide improved attention management

Example of Improvements

1. Improved color-coding



2. Provided better feedback as to what LACS is completing and what taskings operator needs to accomplish



Example of Improvements

Provided needed information and better organization of information to support operator tasking

Thank you for your time

Any Questions?